5W2H as a Flexible Analytical Framework for Investigating Programming Teaching and Learning Across Different Methodological Designs

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Abstract

Teaching and learning programming in Higher Education is a complex process involving cognitive, pedagogical, contextual, and metacognitive dimensions. Traditional analyses focused only on final learning outcomes, such as code correctness, performance, or pass/fail rates, may not fully capture how students construct knowledge, face difficulties, mobilize strategies, and interact with different learning contexts. This article discusses the use of the 5W2H framework as a flexible analytical tool in two doctoral studies on programming teaching and learning. The first study used 5W2H to organize and triangulate data from a mixed-methods single case study on the teaching and learning of programming in a Higher Education course. The second study articulated 5W2H with the spiral model and Bloom's revised taxonomy to analyze a qualitative multiple case study focused on students' algorithm construction process. Through a comparative analysis, the article shows that 5W2H can operate at different analytical scales: as a broad structure for mapping subjects, contexts, methodologies, difficulties, and learning factors, and as a process-oriented framework for interpreting students' actions during algorithmic problem solving. The findings suggest that 5W2H supports the organization, categorization, triangulation, and interpretation of complex educational data. Therefore, the framework offers a useful methodological lens for research in programming education, helping researchers understand the relationships between subjects, contexts, strategies, difficulties, and cognitive processes involved in teaching and learning programming.

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1 Introduction

The teaching and learning of programming are part of the curricular guidelines of Computing and related courses [15]. However, this process remains challenging for both teachers and students. Teaching programming requires strategies to monitor, guide, assess, and support students with different profiles and levels of prior knowledge [5]. Learning to program, in turn, requires constant practice and the development of skills such as problem solving, logical reasoning, abstraction, interpretation, and algorithmic thinking [3, 17, 9, 14]. When these dimensions are not adequately supported, students may experience demotivation, frustration, failure, or dropout [13].

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Because of this complexity, the analysis of programming education cannot be restricted to final learning outcomes, such as grades, code correctness, performance, or pass/fail rates. These indicators are relevant, but they do not fully explain how students understand problems, mobilize prior knowledge, construct algorithms, deal with errors, adapt strategies, and interact with different learning contexts. Therefore, research in this field requires analytical structures capable of organizing multiple sources of evidence and relating cognitive, pedagogical, contextual, and metacognitive dimensions.

In this context, the 5W2H framework offers a structure for organizing and interpreting data through seven guiding parameters: “What”, “Who”, “Where”, “When”, “Why”, “How”, and “How Much” [6, 8, 7, 10]. Although traditionally associated with planning and management, 5W2H can also be adapted as an analytical framework, especially when the phenomenon under investigation involves multiple actors, contexts, actions, reasons, strategies, and impacts.

This article discusses the use of 5W2H in two doctoral studies conducted in the field of Educational Sciences, both focused on programming teaching and/or learning in Higher Education. The first study [11] aimed to understand how the process of teaching and learning programming occurs in Higher Education, seeking to identify methodologies, tools, learning factors, required knowledge and skills, difficulties faced by teachers and students, and the consequences of these difficulties.

The second study [16] aimed to understand how students in an introductory programming course assimilate and use programming logic concepts in the construction of algorithms. Its analytical focus was the process through which students assimilate, accommodate, and equilibrate new programming knowledge, in dialogue with Piaget’s genetic epistemology [12].

Although the two studies adopted different methodological designs, both used 5W2H to organize, categorize, triangulate, and interpret data. In the first study, the framework served as a broad structure for triangulating evidence from documents, questionnaires, and interviews. In the second, it was articulated with the spiral model and Bloom’s revised taxonomy to support a more process-oriented analysis of students’ actions during algorithm construction.

Despite previous uses of 5W2H as a planning and management tool, its potential as an analytical framework in educational research, particularly in programming education, remains comparatively less discussed. This article contributes to this gap by examining how 5W2H can be methodologically adapted to support different research designs and analytical scales in studies on programming teaching and learning.

Based on this context, this article is guided by the following research question: how can the 5W2H framework support the organization, triangulation, and interpretation of data in doctoral studies on programming teaching and learning developed with different methodological designs? To answer this question, the article presents and compares the methodological adaptation of 5W2H in the two studies, highlighting its role in organizing data sources, supporting evidence triangulation, and interpreting contextual, pedagogical, cognitive, and metacognitive dimensions.

The remainder of this article is organized as follows. First, the 5W2H framework is presented as an analytical tool for educational research. Next, the methodological approach of this article is described. The following section explains how 5W2H was applied in the two doctoral studies. Then, a comparative analysis discusses similarities, differences, analytical scales, and methodological functions of the framework. Finally, the discussion, limitations, and conclusion sections address the contributions, challenges, and potential of 5W2H as a methodological resource for research on programming teaching and learning.

2 5W2H as an Analytical Tool

The 5W2H framework is traditionally recognized as a management and planning tool used to structure ideas, projects, tasks, actions, or problems in a clear and systematic way. Its logic consists of answering seven guiding questions: What, Who, Where, When, Why, How, and How Much. These questions make it possible to examine different aspects of a problem in an articulated manner, avoiding analyses restricted to a single dimension of the phenomenon under investigation [7].

Although 5W2H is widely used in areas such as business, strategy, planning, quality management, and process organization, its structure can be adapted to different analytical contexts. Previous studies have reported its application in areas such as gamification, programming language development, software requirements reuse, product design, safety analysis, and programming education [6, 8, 20, 2, 4, 10]. In Educational Sciences, it has also been explored mainly as a tool for planning, organizing, and managing pedagogical or institutional actions. For example, Veiga et al. [19] used SWOT and 5W2H to support collaborative pedagogical planning aimed at promoting equity in Distance Education. Other applications have associated the framework with the design and evaluation of gamified educational systems [6].

However, many of these applications approach 5W2H primarily as an operational tool for planning, intervention design, or management. Its use as an analytical framework for organizing, categorizing, triangulating, and interpreting empirical data in educational research remains less discussed. This distinction is central to the present article: here, 5W2H is not treated as a prescriptive action plan, but as a methodological structure for analyzing complex educational phenomena, particularly in studies on programming teaching and learning.

The analytical potential of 5W2H lies in its ability to decompose a complex situation into interrogative dimensions. The What parameter identifies the action, problem, object, or phenomenon under analysis; Who directs attention to the subjects involved; Where situates the phenomenon in a context or institutional setting; When introduces the temporal dimension; Why explores reasons, causes, or difficulties; How describes processes, strategies, methods, or procedures; and How Much observes intensity, quantity, frequency, effort, cost, recurrence, relevance, or impact.

In educational research, the How Much parameter requires particular adaptation. Unlike its traditional use in management contexts, where it is often associated with cost or measurable resources, in educational studies it may refer to the perceived intensity of difficulties, recurrence of behaviors, frequency of strategies, relevance attributed by participants, or impact of a given condition on teaching and learning. Thus, the framework can be adapted without reducing educational phenomena to exclusively quantitative dimensions.

In research on programming teaching and learning, this multidimensional structure is particularly relevant because the phenomenon involves technical, cognitive, pedagogical, contextual, social, and metacognitive dimensions. Programming is not limited to writing code or achieving final performance indicators; it involves subjects who teach and learn, institutional contexts, moments in the educational pathway, conceptual difficulties, problem-solving strategies, forms of mediation, and different levels of effort or impact. From this perspective, 5W2H can function as an analytical lens that connects subjects, contexts, actions, reasons, strategies, and impacts, providing the basis for the comparative discussion developed in this article.

3 Methodological Approach

This article adopts a comparative and methodological-reflective approach. It does not aim to reanalyze the empirical data produced in the two doctoral studies, but to examine how the 5W2H framework was used as an analytical structure in each study. Therefore, the focus of the analysis is not on the empirical results of the studies themselves, but on the methodological role played by 5W2H in the organization, categorization, triangulation, and interpretation of data.

The corpus of analysis consists of two doctoral studies conducted in the field of Educational Sciences, in the specialty of Educational Technology, both focused on the teaching and/or learning of programming in Higher Education. The first study adopted a mixed-methods single case study design, while the second adopted a qualitative multiple case study design. These studies were selected because they share a common object of investigation, programming teaching and learning, but differ in their methodological designs, analytical scales, data sources, and ways of applying the 5W2H framework.

To make the methodological basis of the comparison explicit, Table 1 summarizes the main characteristics of the two doctoral studies.

Table 1 Methodological characteristics of the two doctoral studies.

Aspect	**Study 1**	**Study 2**
Research focus	Teaching and learning programming in Higher Education	Programming learning and algorithm construction in introductory programming
Research design	Mixed-methods single case study	Qualitative multiple case study
Context	Higher Education course in Informatics in the Brazilian context	Introductory programming contexts in Higher Education, including formal and non-formal contexts
Participants	Students and teachers from a Higher Education course in the field of Informatics	Students participating in introductory programming learning contexts
Data sources	Documents, questionnaires, and interviews with students and teachers	Semi-structured interviews, clinical interviews, and digital and paper-based records
Analysis procedures	Content analysis and interpretation, followed by categorization according to the theoretical framework and 5W2H parameters	Content analysis supported by NVivo, articulated with the spiral model, Bloom's revised taxonomy, and 5W2H
Validation and triangulation	Triangulation of multiple sources of evidence: documents, questionnaires, and interviews	Triangulation of interviews, students' explanations, algorithmic productions, and digital/paper records
Role of 5W2H	Broad analytical matrix for organizing and triangulating evidence about subjects, contexts, difficulties, factors, methodologies, tools, and consequences	Process-oriented analytical structure for interpreting students' actions, strategies, difficulties, effort, and reflections during algorithm construction

Source: Prepared by the authors.

In addition to the methodological descriptions of the two doctoral studies, the analysis also considered reflective accounts produced by the principal investigators regarding the role, advantages, challenges, and limitations of using 5W2H in their respective studies. These reflections were used to support the interpretation of how the framework operated in each study and to identify the conditions under which 5W2H contributed to data organization, triangulation, and analytical interpretation.

The comparative analysis was organized around five dimensions: the object of analysis of each study; the methodological design adopted; the function attributed to the 5W2H framework; the analytical scale at which the framework was applied; and the reflective assessment of the framework by the principal investigators. This procedure made it possible to identify similarities and differences between the two applications of 5W2H and to discuss its potential as a flexible analytical framework for research in programming education.

Thus, the methodological contribution of this article lies in examining how 5W2H can be adapted from its traditional use as a planning and management tool to operate as an analytical framework capable of supporting different stages of educational research, including the organization of evidence, the triangulation of data sources, and the interpretation of complex teaching and learning processes.

4 Application of the 5W2H Framework in the Doctoral Studies

This section describes how the 5W2H framework was applied in each doctoral study, highlighting its analytical function, the data sources involved, and its contribution to the organization and interpretation of the investigated phenomenon.

4.1 Application of 5W2H in Study 1

Study 1, entitled *Teaching and Learning Programming: A Case Study in Higher Education*, aimed to understand how the process of teaching and learning programming occurs in Higher Education. To this end, it sought to inventory methodologies and tools, characterize factors that influence learning, explain the knowledge and skills required to learn programming, and identify difficulties faced by teachers and students, as well as the consequences of these difficulties.

The research adopted a mixed-methods approach and was developed through a single case study in a Higher Education course in the field of Informatics in the Brazilian context. Data were collected through documents, questionnaires, and interviews with students and teachers. After collection, the data were subjected to content analysis and interpretation. Subsequently, triangulation of the sources of evidence was carried out, categorized in light of the theoretical framework and according to the parameters of the 5W2H framework.

In this study, 5W2H was used to support the categorization of units of record obtained from different data sources. After the development of conceptual maps related to the research objectives, it was possible to refine and characterize the parameters used to analyze the learning process. These parameters were organized according to 5W2H and served as the basis for analyzing students' and teachers' perceptions of the investigated process.

In this study, the framework assumed a broad organizational function for the phenomenon. It made it possible to structure information according to the seven 5W2H parameters: What, by identifying factors, competencies, knowledge, and skills required for learning programming; Who, by considering the participants involved in the process; Where, by situating the contexts in which learning occurs; When, by observing moments in the educational pathway; Why, by examining reasons associated with difficulties; How, by analyzing the ways in which teachers and students act; and How Much, by considering the intensity or impact of the factors analyzed. Thus, 5W2H supported data triangulation and the construction of an integrated reading of programming teaching and learning, as shown in Figure 1.

Figure 1 Broad organizational function of 5W2H in Study 1.

4.2 Application of 5W2H in Study 2

Study 2, entitled *Programming Learning in Higher Education: A Multiple Case Study on Cognitive and Contextual Factors*, focused on understanding how students in an introductory programming course assimilate and use programming logic concepts in the construction of algorithms. The study adopted a qualitative approach and used a multiple case study methodology.

To achieve this understanding, meetings were held with students using semi-structured interviews, clinical interviews, and digital and paper-based records as data collection instruments. The data were analyzed through content analysis and organized using the spiral software development model [18], Bloom's revised taxonomy [1], and the 5W2H framework. The spiral model structured the activity-solving process into phases, from goal definition to evaluation of the constructed solution; Bloom's taxonomy related these phases to the types of knowledge mobilized by students; and 5W2H provided a systematic structure for organizing and interpreting students' actions throughout the coding process, from the initial understanding of the problem to the final tests, as shown in Figure 2.

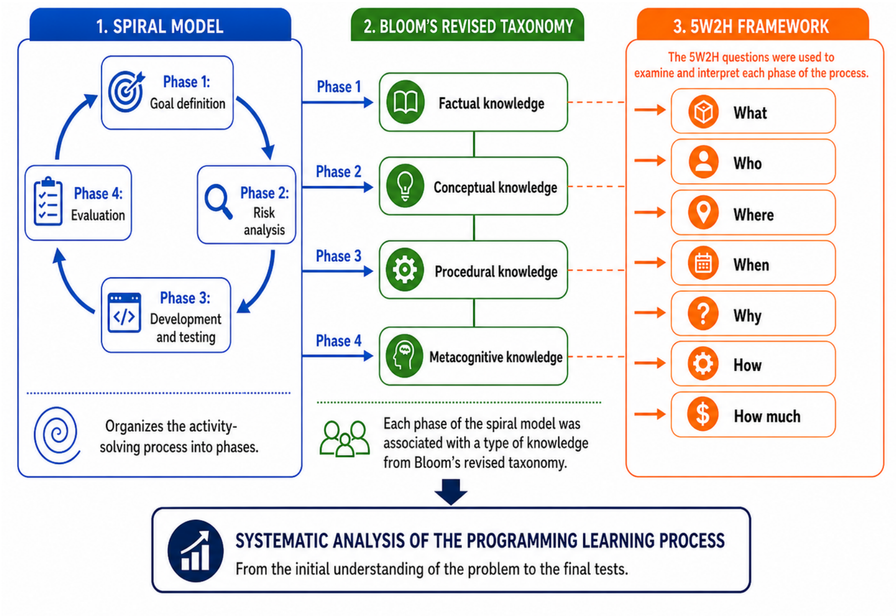

Figure 2 Articulation between the Spiral Model, Bloom's Revised Taxonomy and 5W2H.

5 Comparative Analysis of the Applications of 5W2H

The comparison between the two studies shows that the 5W2H framework was used in both as an instrument for organizing and interpreting data on programming teaching and/or learning in Higher Education. However, its role differed according to the object of analysis, methodological design, data sources, and analytical scale of each study.

The first difference concerns the object of analysis. Study 1 analyzed programming teaching and learning in a broad way, considering methodologies, tools, learning factors, required knowledge and skills, difficulties faced by teachers and students, and the consequences of these difficulties. Study 2 focused more specifically on programming learning, seeking to understand how introductory programming students assimilate and use programming logic concepts in the construction of algorithms.

The second difference lies in the methodological design. Study 1 adopted a mixed-methods single case study, using documents, questionnaires, and interviews with students and teachers from a Higher Education course in Informatics in the Brazilian context. Study 2 adopted a qualitative multiple case study, using semi-structured interviews, clinical interviews, and digital and paper-based records with students from formal and non-formal programming learning contexts.

These methodological differences influenced how 5W2H was applied. In Study 1, the framework organized a broader reading of the phenomenon, allowing data to be categorized according to parameters capable of encompassing subjects, contexts, methodologies, tools, learning factors, difficulties, and impacts. In Study 2, 5W2H was used in a more process-oriented analysis, aimed at understanding how students moved through different moments of learning: before solving the activities, during algorithm construction, and in the outcome/reflection after solving them.

The third difference refers to the level of granularity of the analysis. In Study 1, 5W2H supported a macro-level analysis of programming teaching and learning as an institutional, pedagogical, and educational phenomenon. In Study 2, the framework was combined with the spiral model and Bloom's revised taxonomy to support a more fine-grained analysis of students' actions during algorithm construction, including goal definition, risk analysis, development and testing, and evaluation.

Despite these differences, both studies converge in recognizing programming teaching and learning as complex processes composed of multiple interdependent factors. In both cases, 5W2H helped avoid a fragmented reading of the phenomenon by organizing information about subjects, contexts, actions, reasons, strategies, and impacts. This convergence shows the methodological flexibility of the framework: in one study, it functioned as a broad matrix for categorizing and triangulating data; in the other, it was integrated with complementary models to analyze specific learning processes.

Table 2 summarizes the main differences between the two uses of 5W2H, focusing on analytical scale, categorization, triangulation, articulation with other frameworks, and methodological contribution.

Table 2 Comparative analysis of the use of 5W2H in the two studies.

Compared aspect	**Study 1**	**Study 2**
Analytical scale	Macro-level analysis of the teaching and learning process in a Higher Education course	Micro/process-oriented analysis of students' algorithm construction
Main function of 5W2H	Broad matrix for organizing and triangulating evidence from different sources	Analytical structure for interpreting students' actions across stages of problem solving
Focus of categorization	Factors, participants, contexts, difficulties, methodologies, tools, and consequences related to programming teaching and learning	Students' understanding, planning, coding, testing, correction, effort, and reflection during algorithm construction
Use in triangulation	Direct triangulation of documents, questionnaires, and interviews through the 5W2H parameters	Triangulation of interviews, students' explanations, and digital/paper records, articulated with other analytical models
Articulation with other frameworks	Used mainly in relation to the theoretical framework and content analysis categories	Combined with the spiral model, Bloom's revised taxonomy, and Piaget's genetic epistemology
Methodological contribution	Supports an integrated reading of programming teaching and learning as an institutional, pedagogical, and contextual phenomenon	Supports a fine-grained interpretation of cognitive and metacognitive processes involved in algorithm construction

Source: Prepared by the authors.

To illustrate how 5W2H was operationalized in practice, the two studies provide different examples of analytical use. In Study 1, students' reports on difficulties with programming logic, abstraction, problem interpretation, and basic programming concepts were categorized under What as learning difficulties. The same evidence was interpreted under Why when the analysis focused on possible causes, such as insufficient prior knowledge or abstraction barriers, and under How Much when the focus was on perceived effects, such as demotivation, failure, or dropout. Evidence from documents, questionnaires, and interviews was also associated with Who, Where, When, and How, allowing the study to relate participants, institutional context, curricular organization, and teaching strategies in the triangulation of teachers' and students' perceptions.

In Study 2, 5W2H was operationalized at a more process-oriented level. Students' actions during problem reading, solution planning, coding, testing, and correction were associated with What, When, and How, making it possible to identify what was being solved, when each action occurred in the phases of the spiral model, and how students proceeded. Their explanations, uncertainties, revisions, and reflections were associated with Why and How Much, supporting the interpretation of reasons for decisions, difficulties faced, effort involved, recurrence of corrections, and evidence of conceptual or metacognitive adjustment.

These examples show that 5W2H did not operate merely as a descriptive checklist. In both studies, empirical evidence was associated with one or more parameters and then interpreted in relation to the research objectives and theoretical frameworks. This illustrates how the framework supported the movement from data organization to analytical interpretation.

Thus, the comparative analysis allows us to state that 5W2H is not limited to a planning tool or an initial organizational instrument. In both studies, it assumed an analytical function, supporting the categorization, triangulation, and interpretation of data. This function makes the framework relevant for research on programming teaching and learning, especially when the aim is to understand complex phenomena involving subjects, contexts, strategies, difficulties, and cognitive processes.

6 Discussion: 5W2H as an Analytical Framework for Research on Programming Teaching and Learning

The main contribution of this article lies in showing that 5W2H can be methodologically adapted from its traditional role as a planning and management tool to function as an analytical framework in programming education research. This contribution does not consist of proposing a new learning theory, a new pedagogical model, or a new technique for content analysis. Rather, its contribution lies in its use as an integrative analytical matrix capable of organizing and relating different dimensions of complex educational phenomena.

Several consolidated frameworks already contribute to the analysis of programming teaching and learning. Bloom's revised taxonomy, for example, supports the identification of cognitive processes and types of knowledge mobilized by students [1]. The spiral model helps structure phases of problem solving, development, testing, and evaluation [18]. Content analysis provides procedures for coding, categorizing, and interpreting empirical material. Learning theories, such as Piaget's genetic epistemology, contribute to explaining how knowledge may be constructed, reorganized, and stabilized throughout the learning process [12].

The role of 5W2H is different. It does not replace these frameworks; instead, it provides an interrogative structure that helps connect them. By asking What, Who, Where, When, Why, How, and How Much, the framework allows researchers to relate the object of analysis, the participants involved, the context, the temporal organization of the process, the reasons for difficulties or decisions, the strategies adopted, and the intensity, recurrence, or impact of the observed phenomena.

In Study 1, this adaptation supported the organization and triangulation of heterogeneous sources of evidence related to the teaching and learning of programming. In Study 2, it supported a more process-oriented analysis of students' actions during algorithm construction, especially when articulated with the spiral model and Bloom's revised taxonomy. Thus, 5W2H contributes not by explaining learning on its own, but by helping researchers structure the relationships among empirical evidence, theoretical categories, participants, contexts, actions, reasons, strategies, and impacts.

The comparison between the two studies also suggests that 5W2H performed three complementary analytical functions. First, it had an organizational function by structuring heterogeneous data from documents, questionnaires, interviews, records, and students' productions. Second, it had an integrative function by connecting data sources, analytical categories, and theoretical references, especially in the triangulation process in Study 1 and in the articulation with the spiral model and Bloom's revised taxonomy in Study 2. Third, it had an interpretive function by allowing difficulties, strategies, contexts, actions, and impacts to be analyzed in relation to one another rather than as isolated elements. These functions help clarify the methodological contribution of 5W2H as an analytical layer for programming education research.

Its originality therefore lies in its methodological function as a flexible and integrative analytical layer, capable of supporting different research designs and analytical scales in programming education.

6.1 Reflections from the Principal Investigators

From the perspective of the principal investigator of Study 1, the main contribution of 5W2H was its ability to organize heterogeneous data sources within a coherent analytical structure. Since the study involved documents, questionnaires, and interviews with both teachers and students, the framework helped relate different types of evidence to the same analytical dimensions. This facilitated triangulation and supported a broader understanding of the teaching and learning process. However, one challenge observed was the need to adapt some parameters, especially How Much, since educational phenomena are not always expressed through direct numerical indicators or measurable costs.

From the perspective of the principal investigator of Study 2, 5W2H was particularly useful because it allowed the analysis of students' actions during algorithm construction without isolating these actions from their context, motivations, difficulties, and strategies. When articulated with the spiral model and Bloom's revised taxonomy, the framework helped organize evidence about how students understood problems, planned solutions, tested hypotheses, corrected errors, and reflected on their own learning. Nevertheless, this use also required careful articulation with other theoretical models, since 5W2H alone does not explain cognitive development or learning processes.

These reflections indicate that the value of 5W2H in educational research does not lie in mechanically applying its seven questions. Its analytical strength depends on adapting the framework to the nature of the phenomenon under investigation, the research objectives, the data sources, and the theoretical assumptions of each study. In this sense, 5W2H should be understood as an organizing and interpretive layer rather than as a self-sufficient analytical method.

Overall, the two studies show that 5W2H can support research on programming teaching and learning by helping researchers move between broader contextual dimensions and more specific learning trajectories. From a macro perspective, it can organize institutional, pedagogical, and curricular aspects of programming education. From a micro perspective, it can support the analysis of students' actions, decisions, difficulties, strategies, and reflections during algorithm construction.

This flexibility is precisely what makes the framework relevant as a methodological resource for programming education research.

7 Limitations and Challenges of Using 5W2H

Although the 5W2H framework proved useful for organizing, triangulating, and interpreting data in the two studies analyzed, its use also presents limitations and challenges. First, 5W2H is not a learning theory, a pedagogical model, or a data analysis method by itself. Therefore, it should not be used as a substitute for theoretical frameworks or systematic analytical procedures. Its value depends on its articulation with research objectives, theoretical assumptions, data sources, and methods of analysis.

Second, the framework may lead to superficial or merely descriptive categorization if applied mechanically. Simply assigning empirical evidence to the questions What, Who, Where, When, Why, How, and How Much does not guarantee analytical depth. The researcher must interpret the relationships among these dimensions and connect them to the research problem. Without this interpretive movement, 5W2H risks becoming only a checklist.

Third, some parameters may overlap during the categorization process. For example, a student's difficulty in understanding an algorithmic problem may be related to What, when the focus is on the difficulty itself; to Why, when the focus is on its causes; and to How, when the focus is on the strategies used to overcome it. This overlap does not invalidate the framework, but it requires clear operational definitions and consistent coding decisions.

Fourth, the How Much parameter requires particular adaptation in educational research. In management contexts, this dimension is often associated with cost, quantity, time, or measurable resources. In educational studies, however, it may refer to perceived intensity, recurrence, relevance, effort, or impact. This adaptation increases the flexibility of 5W2H, but also requires methodological caution to avoid imprecise or arbitrary interpretations.

Finally, 5W2H does not explain learning processes on its own. In Study 2, for example, its analytical role depended on its articulation with the spiral model, Bloom's revised taxonomy, and Piaget's genetic epistemology. Similarly, in Study 1, its contribution depended on its integration with content analysis and triangulation procedures. Therefore, the framework should be understood as an organizing and integrative analytical layer, not as a self-sufficient explanatory model.

These limitations indicate that the use of 5W2H in educational research requires careful methodological planning. Its strength lies in helping researchers organize complex phenomena and relate different analytical dimensions, but its effectiveness depends on how rigorously the parameters are defined, applied, and interpreted.

8 Conclusion

This article presented and discussed the methodological adaptation of the 5W2H framework in two doctoral studies on programming teaching and learning in Higher Education. Although the studies adopted different methodological designs, both used 5W2H to organize, categorize, triangulate, and interpret data related to complex educational phenomena.

The comparative analysis showed that 5W2H can operate at different analytical scales. In Study 1, it functioned as a broad matrix for organizing and triangulating heterogeneous sources of evidence related to teaching and learning programming, including documents, questionnaires, and interviews with students and teachers. In Study 2, it supported a more process-oriented analysis of students' actions during algorithm construction, especially when articulated with the spiral model and Bloom's revised taxonomy.

The main contribution of this article lies in showing that 5W2H can be used not only as a planning or management tool, but also as an integrative analytical framework in educational research. Its value is not in replacing consolidated theoretical or methodological frameworks, but in helping researchers connect subjects, contexts, actions, reasons, strategies, and impacts across different data sources and levels of analysis.

The examples of operationalization presented in this article indicate that 5W2H can support the movement from empirical evidence to analytical interpretation. By associating data with the parameters What, Who, Where, When, Why, How, and How Much, the framework helps researchers avoid fragmented readings of programming teaching and learning and favors a more systematic understanding of the relationships among the dimensions involved.

However, the use of 5W2H requires methodological caution. The framework does not explain learning processes by itself and should not be applied mechanically as a checklist. Its analytical strength depends on clear operational definitions, careful categorization procedures, triangulation strategies, and articulation with theoretical models and data analysis methods.

As future work, further studies may apply 5W2H in other programming education contexts, including different institutions, teaching modalities, educational levels, student profiles, and programming courses. Such studies may contribute to refining the framework, testing its analytical robustness, and expanding its use as a methodological resource in Computing Education research.

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